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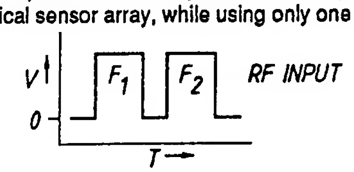
(54) Optical sensing systems

(57) An optical sensing system comprises a laser 1 which illuminates an acousto-optic modulator 11 with a continuous light beam 10. The modulator 11 is driven by pulse pair F_1-F_2 to deflect the beam to optical sensor array 15. When the modulator 11 is not driven, the light beam passes through and is reflected by mirrors 21, 22, 23 and 24 back to a spaced portion of the modulator 11 where it is deflected to a second optical sensor array 26. The arrangement therefore enables one acousto-optic modulator 11 to drive more than one optical sensor array, while using only one deflector.



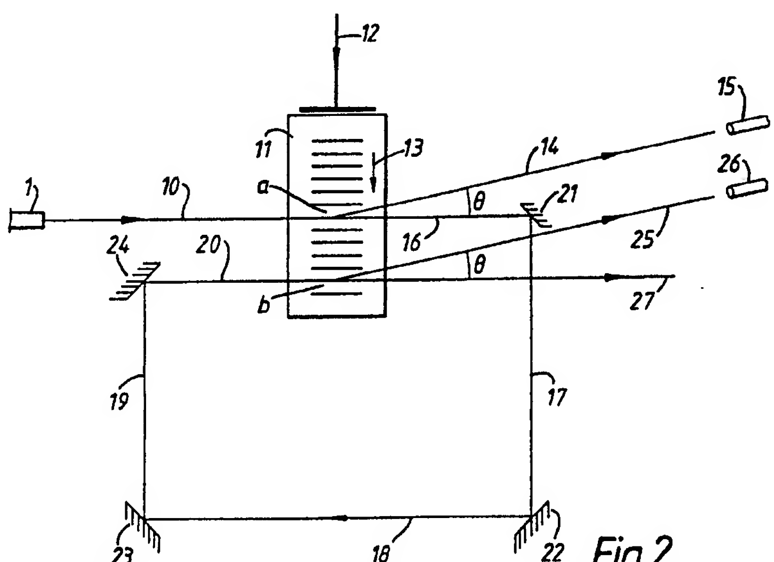


Fig.2.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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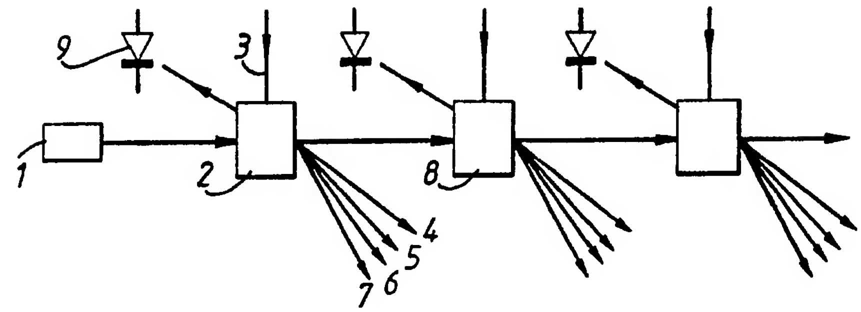

Fig.1.
(PRIOR ART)

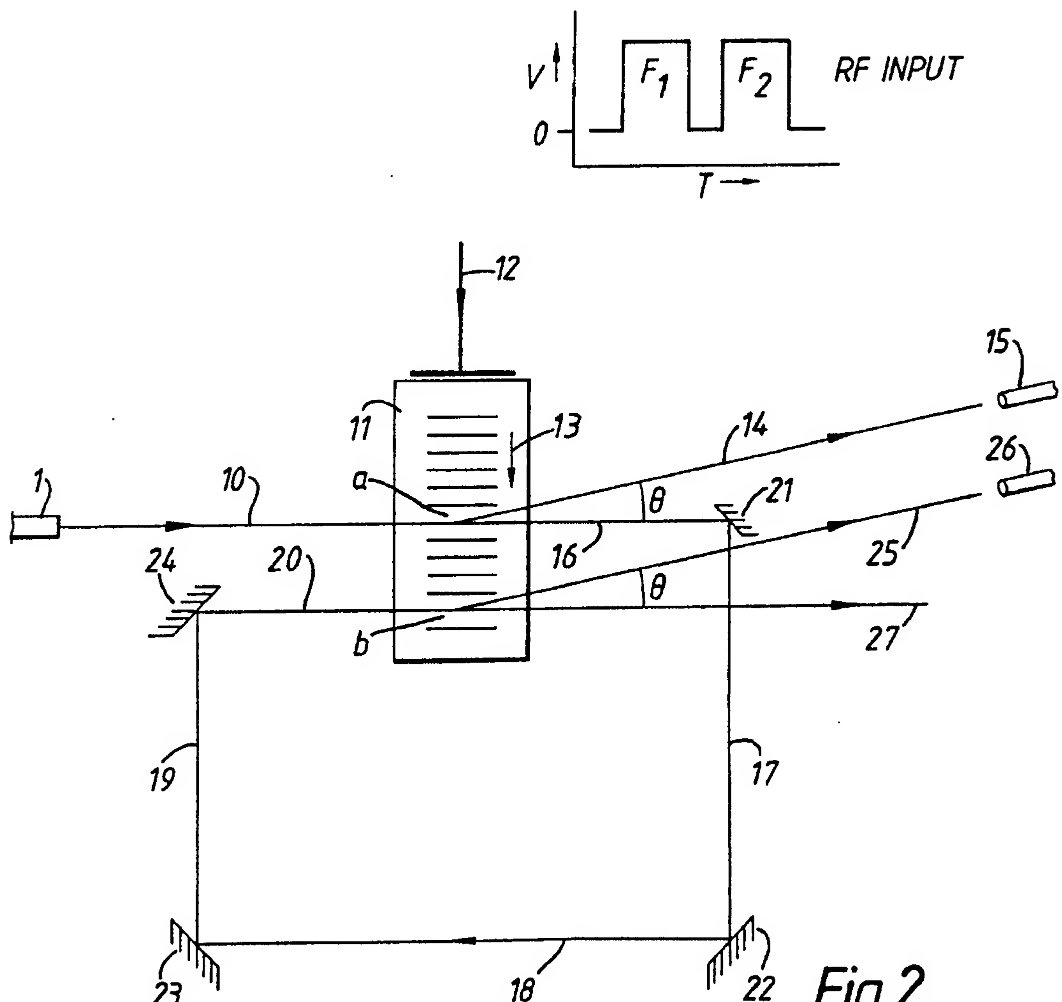

Fig.2.

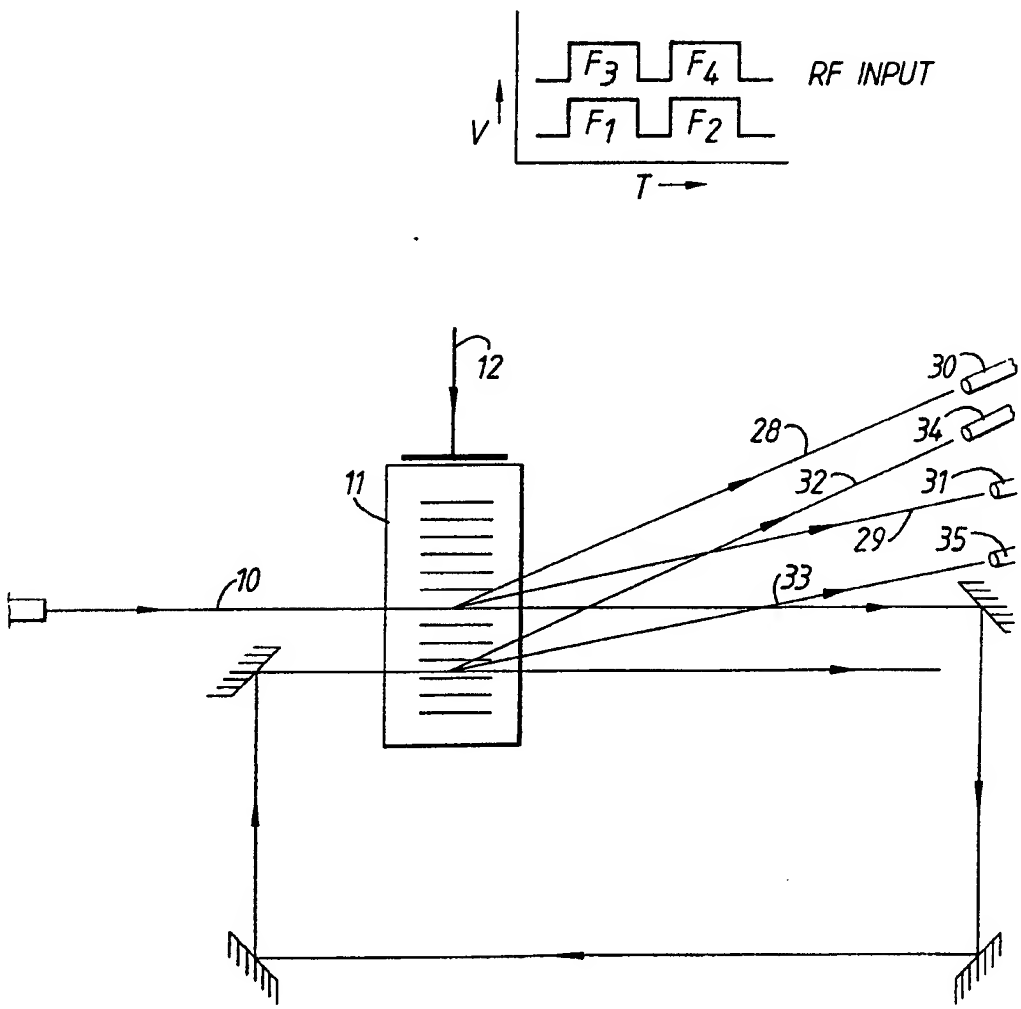

Fig.3.

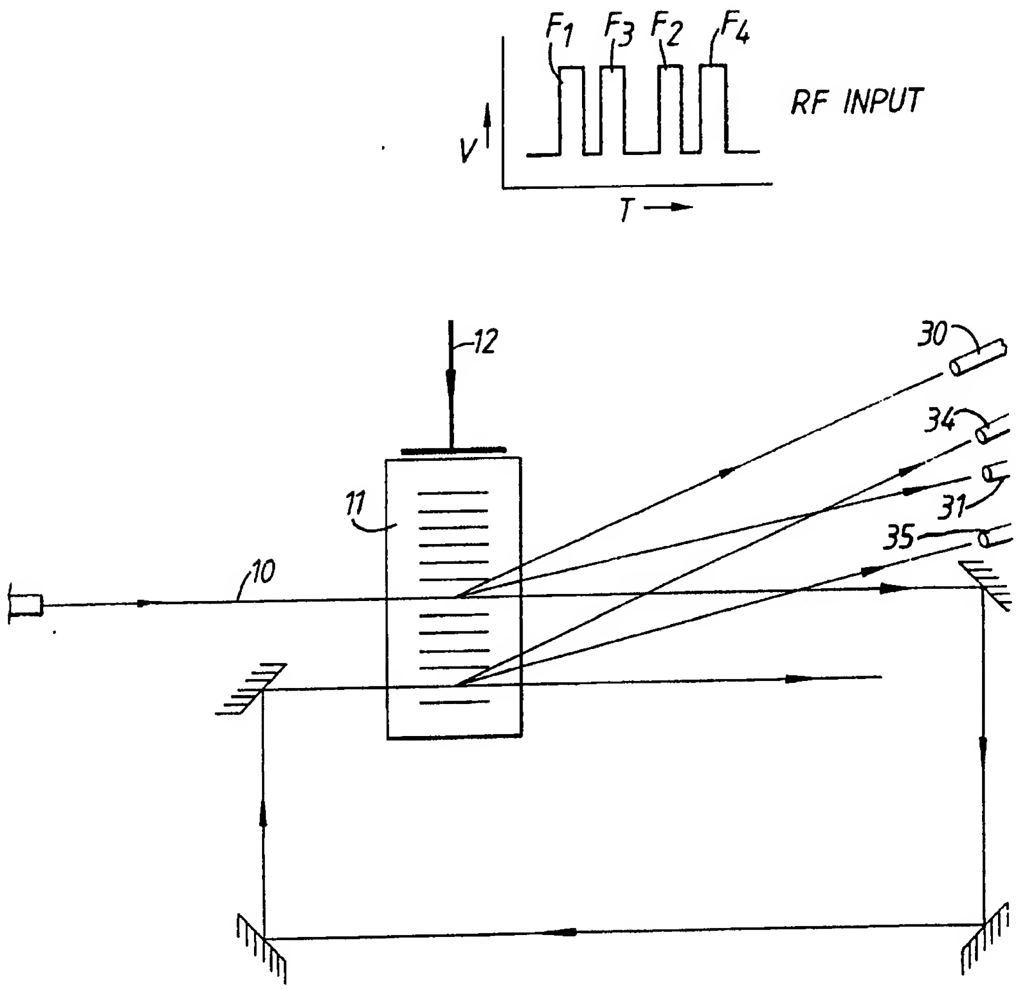

Fig.4.

Optical Sensing Systems

This invention relates to optical sensing systems.

One type of optical sensing system comprises an optical fibre having a number of discontinuities made along its length. A laser is used to provide light which is input or launched in to the fibre and the light is partially reflected at each discontinuity back along the fibre to a detector. The way in which the light propagates along the fibre is affected by pressure or other enviromental effect applied to each section between adjacent pairs of discontinuities, each section being a sensor and a complete fibre forming an array of sensors. Such arrays have many applications and because their sensitivity is great they can be used as hydrophone arrays, sensing pressure waves in water which may be caused by surface or undersurface vessels. Such an optical sensor array is described in United Kingdom patent application no. 2126820.

For economy, it is usual to drive a number of sensor arrays from one laser. Patent application EP 0299638 describes multiplexing arrangements which use a number of Bragg cells in series. The cells, when actuated, deflect a

beam of light into an associated array or arrays but when not actuated allow the light to pass through to the next cell. This is shown in Figure 1 in which light from a laser 1 is directed to a Bragg cell 2. When the cell 2 is driven by an r.f. signal applied to input 3, the light is deflected in directions 4, 5, 6 and 7, each direction corresponding to particular frequencies of applied r.f. signal. The deflected light is then launched into fibre optic sensor arrays (not shown). When the cell 2 is not driven, the light propagates to the next Bragg cell 8 which in turn may be actuated to reflect the light in a similar manner. Light reflected by discontinuities in each array, passes through the cell 2 to be detected by detector 9.

According to the invention there is provided an optical sensor system comprising a light source; two or more optical sensor arrays; light deflection means actuable to deflect light received from the light source, from a first direction to a first sensor array; and light recirculating means for returning light propagating in the first direction to the deflection means where it is deflected into a second sensor array.

By recirculating the light, it is therefore possible to double the number of optical sensor arrays that can be driven

by the light deflection means. Light that is not deflected on its second pass through the light deflection means may also be recirculated in a similar manner allowing even more optical sensor arrays to be used with the one light deflection means. Each sensor array may be an arrangement of a number of associated sensors or a single sensor. The sensor array may be an optical fibre having discontinuities as previously described or some other type of optical sensor. By light it is meant electromagnetic radiation which may be visible, infra-red or ultra violet radiation.

Alternatively, where more sensor arrays are to be driven the deflection means may be actuable to divide the incident light beam and recirculated light beam each into two or more resultant beams and to direct the resultant beams substantially simultaneously to respective optical sensor arrays.

Where more than four sensor arrays are to be driven the incident light beam and recirculated light beam would have to be divided into more than two beams, for example, where six sensor arrays are to be driven the beams would each have to be divided into three. Whilst this would allow more optical sensor arrays to be driven it should be noted that the power would also be divided because the optical sensor arrays are

driven simultaneously. This would mean that fewer sensors per array could be used.

Where it is desired to drive a number of arrays, for example four sensor arrays, and it is also desired to use a large number of sensors per array, the deflection means is, preferably, actuable to deflect the incident light beam sequentially into first and then second optical sensor arrays and the recirculated light beam sequentially into third and fourth optical sensor arrays.

Preferably, the light recirculating means comprises at least one reflector. The reflector could be a polished metal surface or a layer of silvering applied to glass or plastics material. Whilst it is envisaged that a reflector would be most convenient other means could be used for recirculating the light for instance the light could be recirculated by means of an optical fibre or by means of an optical system which might include a prism or prisms.

Conveniently, the deflection means may comprise an acousto-optic modulator. An acousto-optic modulator requires the application of a radio frequency wave to generate an acoustic wave which propagates through the cell. The effect on a light beam as the acoustic wave passes, is that the

light beam is deflected by an amount which is dependent upon the frequency of the acoustic wave which is in turn dependent upon the frequency of the generating wave. If two r.f. pulses are applied simultaneously the light beam is divided in to two deflected beams.

According to a second aspect of the invention, in its broadest sense, there is provided a method of operating an optical sensing system comprising selectively deflecting light, with a light deflection means, to a first sensor array, recirculating undeflected light to the light deflection means and deflecting the recirculated light to a second optical sensor array.

Advantageously, where it is desirable to operate even more optical sensor arrays, the light may be sequentially deflected to first and second optical sensor arrays and the recirculated light sequentially deflected to third and fourth optical sensor arrays.

Alternatively, more optical sensor arrays may be operated by deflecting the light substantially simultaneously to first and second optical sensor arrays and deflecting the recirculated light substantially simultaneously to third and fourth optical sensor arrays.

More specifically the invention provides a method of operating an optical sensing system comprising: illuminating the acousto-optic modulator with a beam of light; applying a pair of radio frequency pulses to the modulator to form an acoustic wave, such that the wave interacts with the beam to deflect it to a first optical sensor array; and recirculating that light which is not deflected to the modulator such that it can interact with the wave and be deflected to a second optical sensor array. The light will therefore have to be recirculated in a way that takes account of the progression of the wave through the modulator in order that the wave and light pass through a region of the modulator at the same time.

Even more arrays may be driven by conveniently, illuminating an acousto-optic modulator with a beam of light; sequentially applying the first and second pairs of radio frequency pulses to the modulator forming first and second respective acoustic waves in the modulator such that the first wave interacts with the beam to deflect it to a first optical sensor array and the second wave interacts with the beam to deflect it to a second optical sensor array; and recirculating light which is not deflected back to the modulator such that it interacts with the waves, the first

deflecting in the light to a third optical sensor array and the second wave deflecting the light to a fourth optical sensor array.

Alternatively four or more optical sensor arrays may be driven by illuminating the acousto-optic modulator with a beam of light; applying at least two pairs of radio frequency pulses substantially simultaneously to form an acoustic wave in the modulator such that the wave interacts with the beam to divide the beam and deflect the resulting beams into first and second optical sensor arrays; and recirculating light which is not deflected to the modulator such that it interacts with the wave and is divided into beams which are deflected into third and fourth optical sensor arrays.

Specific embodiments of the invention will now be described by way of example only with reference to the Figures 2 to 4 of the drawing in which:

Figure 1 shows a prior art optical sensing system;

Figure 2 shows an optical sensing system in accordance with the invention;

Figure 3 shows a further optical sensing system in

accordance with the invention; and

Figure 4 shows a still further optical sensing system in accordance with the invention.

With reference to Figure 2, a continuous wave laser light beam 10 is incident on an acousto-optic modulator 11 which is a Bragg cell formed from a crystal of lead molybdate tetra oxide $PbMoO_4$. The cell 11 is driven by an r.f. pulse pair of frequency F_1-F_2 applied to an input 12 which causes an acoustic wave to be generated and to propagate in the direction of arrow 13 at a velocity of about 3.6 mm per micro second. As the wave passes through region a of the cell 11 through which the beam 10 propagates, the beam 10 is deflected and then propagates along a light path 14 to be launched into a first optical sensor array 15. As the acoustic wave travels away from region a, the beam 10 is no longer deflected but reflected along path 16, 17, 18, 19 and 20 by mirrors 21, 22, 23 and 24. The path lengths are chosen such that the recirculated light and the acoustic wave pass through a second region b of the cell 11 at the same time allowing interaction to occur such that the recirculated light is deflected along path 25 to a second optical sensor array 26. Again as the acoustic wave passes through the region b, the beam ceases to be deflected and propagates

along path 27. This embodiment therefore provides light for the sensor arrays by a time division method.

By applying pulse pairs of different frequencies and recirculating the light, it is possible for a single acousto-optic modulator to drive even further optical sensor arrays as shown in Figure 3. In this embodiment, a pulse pair F_1-F_2 gives rise to a deflected beam 28. A second pulse pair F_3-F_4 gives rise a further deflected beam 29. The beams 28 and 29 drive optical sensor arrays 30 and 31 respectively. As the acoustic wave formed by the pulse pairs passes away from the beam 10, the beam 10 is no longer deflected but is reflected by the mirrors and recirculated as in the previous embodiment. The recirculated beam gives rise to two further deflected beams 32 and 33 which drive optical sensors 34 and 35 respectively under the action of the same acoustic wave that gave rise to the beams 28 and 29. It should be noted that the pulse pairs are applied at the same time and hence the incident beam is split between two arrays halving the power available for each array and consequently allowing fewer sensors to be driven per array than would otherwise be the case. This arrangement is a frequency multiplexing arrangement.

Another embodiment is shown in Figure 4, in which pulse

pairs F_1-F_2, F_3-F_4 are applied sequentially. This causes the beam 10 to be deflected to sensor array 30 under the action of the acoustic wave formed by pulse pair F_1-F_2 and then to sensor array 31 under the action of the acoustic wave formed by pulse pair F_3-F_4. After the passage of the acoustic waves, the light beam is recirculated as in the previously described embodiments. The recirculated light beam is deflected to sensor array 34 under the action of the acoustic wave formed pulse pair F_1-F_2 and to sensor array 35 under the action of the acoustic wave formed by pulse pair F_3-F_4. The arrangement is therefore a frequency/time division multiplexing arrangement.

In alternative embodiments of the invention the light may be recirculated more than once to give an increased multiplexing ratio, that is, even more sensor arrays may be driven from one acousto-optic modulator.

Although there have been described above and illustrated in the drawings various embodiments in accordance with the invention, it will be appreciated that the invention is not limited thereto but encompasses all variations and alternatives within the scope of the claims.

CLAIMS

1. An optical sensing system comprising a light source; two or more optical sensor arrays; light deflection means actuable to deflect light received from the light source, from a first direction to a first sensor array; and light recirculating means for returning light propagating in the first direction to the deflection means where it is deflected into a second sensor array.

2. An optical sensing system as claimed in claim 1 wherein the deflection means is actuable to divide the incident light beam and recirculated light beam each into two or more resultant beams and to direct the resultant beams substantially simultaneously to respective optical sensor arrays.

3. An optical sensing system as claimed in claim 1 wherein the deflection means is actuable to deflect the incident light beam sequentially into first and then second optical sensor arrays and the recirculated light beam sequentially into third and fourth optical sensor arrays.

4. An optical sensing system as claimed in any

preceding claim wherein the light recirculating means comprises at least one reflector.

5. An optical sensing system as claimed in any preceding claim wherein the deflection means comprises an acousto-optic modulator.

6. An optical sensing system as hereinbefore described with reference to and as illustrated by Figures 2, 3 and 4 of the accompanying drawing.

7. A method of operating an optical sensing system having two or more optical sensor arrays comprising selectively deflecting light, with a light deflection means, to a first sensor array, recirculating undeflected light to the light deflection means and deflecting the recirculated light to a second optical sensor array.

8. A method as claimed in claim 7 wherein the light is sequentially deflected to first and second optical sensor arrays and the recirculated light is sequentially deflected to third and fourth optical sensor arrays.

9. A method as claimed in claim 7 wherein the light is deflected substantially simultaneously to first and second

optical sensor arrays and the recirculated light is deflected substantially simultaneously to third and fourth optical sensor arrays.

10. A method as claimed in claim 7 comprising: illuminating an acousto-optic modulator with a beam of light; applying a pair of radio frequency pulses to the modulator to form an acoustic wave such that the wave interacts with the beam, deflecting the beam to a first optical sensor array; and recirculating light which is not deflected to the modulator such that the light can interact with the wave and be deflected to a second optical sensor array.

11. A method as claimed in claim 8 comprising: illuminating the acousto-optic modulator with a beam of light; sequentially applying first and second pairs of radio frequency pulses to the modulator to form first and second respective acoustic waves in the modulator, such that the first wave interacts with the beam to deflect it to a first optical sensor array and the second wave interacts with the beam to deflect it to a second optical sensor array; and recirculating light which is not deflected back to the modulator such that it interacts with the waves, the first wave deflecting the recirculated light to a third optical sensor array and the second wave deflecting the recirculated

light to a fourth optical sensor array.

12. A method as claimed in claim 9 comprising: illuminating an acousto-optic modulator with a beam of light; applying at least two pairs of radio frequency pulses substantially simultaneously to form an acoustic wave in the modulator such that the wave interacts with the beam to divide the beam and to deflect the resulting beams into first and second optical sensor arrays; and recirculating light which is not deflected to the modulator such that it interacts with the wave and is divided into beams which are deflected into third and fourth optical sensor arrays.

13. A method of operating an optical sensing system substantially as hereinbefore described with reference to Figures 2, 3 and 4 of the accompanying drawings.